Floating anchors for the stabilization of Cischele landslide in the Venetian Prealps

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INTRODUCTION
Due to its weather-climatic, geological and geomorphological setting, Italy is particularly subject to geo-hydrological hazard. New alarms intensify during exceptional rainfalls. Therefore, the research for innovative and cost-effective solutions for risk mitigation and landslide stabilization has great scientific and socio-economic relevance. The paper focuses on the stabilization works and monitoring of a landslide located in Cischele (Italy), where an innovative cost-effective intervention with floating anchors have been set up.

THE FLOATING ANCHOR TECHNIQUE
The technique involves the installation of passive nails, cemented along the full length and with a foundation in the deep stable soil. These reinforcements fit the slope according to a discontinuous geometry without a continuous facing. The anchor heads are externally connected only to a small concrete plate (the “floating” element). If the slope deforms and the ground moves, the plates may be englobed into the soil. As opposed to active anchors, in order to slow down the evolution of the landslides, the nails absorb a portion of the shear stress inducing the instability by the frictional contact at the soil-grout interface in the moving mass. In this way, they transfer to the external plates a small tension and they do not require a continuous facing, but only a small head plate. Since the floating anchor is a modular and flexible technique, it offers the advantage to support the slope deformations without losing effectiveness, slowing down the evolitional process until it completely stops (Bisson & Cola, 2014).

The components of a floating anchor are analysed both in physical and numerical models in order to assess their geotechnical and structural behaviour (Bisson, 2015), but their real-scale behaviour was also analysed by installing and monitoring them in some test sites (Bisson et al., 2014).

CISCHELE LANDSLIDE
The exceptional rainfall that in November 2010 affected the Venetian Prealps in Vicenza province activated the movement of some houses and a portion of the main road that connects the Cischele hamlet with Recoaro Terme. The area, approximately 120 m wide and 180 m long, is located at an altitude between 550 and 600 m a.s.l. and has a mean inclination of 24°. Many visible signs of the slow and continuous movement have been observed in the structural elements of the houses and fractures in the walls. The landslide is a slow-moving translational phenomenon with a strong correlation between displacements and change in pore water pressure.

The geotechnical investigation show a soil profile made by a completely weathered Bellerophon limestone cover 10-12 m thick lying above a clayey silt and sandy clay layer originated by the alteration of Val Gardena Sandstone. Below, up to 20 to 30 m from the ground surface, a bedrock of low-medium altered phyllites has been recognized. The sliding occurs at the contact between the Bellerophon and the Sandstones (Fig. 1).

STABILIZATION WORKS
The intervention completed in December 2014 and consisted in 33 floating anchors 40 to 50 m long. Due to the huge depth, special enhanced composite bars (Bisson et al., 2013) have been installed (Fig. 1).
They consist of a self-drilling bar with 7 tendons pretensioned and cemented inside. Thanks to the presence of inner tendons, these nails have an ultimate tensile strength increased from 1400 to 3000 kN with an increment of cost less than 20%.

Two load cells (Fig. 3) record the axial force applied behind two floating plates, while a specifically designed strain gauge strip was installed inside 2 anchor bars to monitor the tension along the passive bars. In the future, the tensional data will be crossed with inclinometers and piezometers data, thus evaluating the correlation between variations in groundwater and superficial/deep movements.

**CONCLUSIONS**

The monitoring of the Cischele stabilized slope permits the analysis of the real-scale behaviour of the floating anchors system. The preliminary results give no significant post-work displacements, thus proving the viability and technical efficiency of the method.

**REFERENCES**